REMOTE BOUNDARY LAYER SENSING - RO3571

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LONG TERM GOALS

Improve the Navy's real-time surveillance and target assessment in critical global environments through the use of radar remote sensing.

OBJECTIVES

Using techniques and facilities in the Environmental Research Laboratories of NOAA, determine the relevance of new advances in remote sensing to Navy needs by accomplishing the following: (1) Develop and test the theory relating temperature and humidity gradients (and, therefore, refractive index gradients) to the moment information contained in the radar Doppler velocity spectra sensed by radars (Gossard et al. 1982, 1997, 1998a). (2) Develop and test the theory for extending the radar observation of cloud drop-size distributions to the small drop domain of the spectra where the past methods fail because of the small drop sizes (Gossard et al. 1998b). (3) Conduct experiments to test the validity of alternate theoretical concepts. (4) Work closely with experts from Navy laboratories to examine the feasibility of incorporating radar remote sensing of the lower atmosphere into Navy operational procedures. Fifty percent of this work is supported by the NOAA/Environmental Technology Laboratory.

APPROACH

State-of-the-art radar facilities to sense remotely the cloud environment and the clear air environment have been designed and constructed at the Environmental Technology Laboratory in Boulder. These facilities offer the opportunity to test the applicability of various remote sensing techniques to Navy problems without the expense of duplicating the facilities in the Navy. The theoretical approaches to the subject are given in the references. The experimental approach is to collect data in appropriate environments where meteorological conditions vary over a wide range and are predictable. (Data on stratus and drizzle have been collected with an 8-mm-wavelength radar in the Azores in ASTEX and with a 449 MHz wind profiling radar in San Diego in a joint experiment with the Naval Command Control and Ocean Surveillance Center.

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An article titled "The potential of 8-mm radars for remotely sensing cloud drop-size distributions," by Gossard et al. 1997, appeared in JTECH. It describes how millimeter wavelength radars can remotely sense drop-size information even into the non precipitating size regime.

RESULTS

During this period, a significant breakthrough occurred while analyzing the radar wind profiler data and balloon data collected at Point Loma in October 1995. The results suggest that height profiles of radar refractive index can be monitored by GPS and a surface-based wind profiler. These data were analyzed in the time period of this report and led to an article by Gossard et al. 1998 in JTECH to appear in January In this experiment the zeroth and second moments of the radar Doppler spectra were examined in addition to the conventional first moment winds. In this experiment the balloon temperature and humidity data were compared with profiler-retrieved refractive-index gradient data, as described in earlier reports to ONR and Naval Ocean Systems Center (NOSC) based on results of Gossard et al. 1982. According to the theory, C_N^2 is proportional to the square of the height-gradient of refractive-index. Therefore, since C_N^2 is proportional to the backscattered power sensed by the radar, the radar can, in principle, provide profiles of the square of the refractive index gradient (note the loss of sign due to the squaring). Until now, it has been assumed that Doppler radar wind profilers could only provide profiles of the gradients, not profiles of refractive index. However, the new availability of GPS-measured total precipitable water vapor, (pwv), (and total refractive index) allows radar-sensed gradients to be integrated with the constraint that the totals equal those found from GPS and initialized with the measured value of surface refractive index. Some results from the Point Loma experiment are shown in the attached figures. In these figures the balloon rises to a height of 2 km in roughly 10 minutes. During this time the radar cycles through its five beam directions (N, S, E, W and vertical) three times, collecting wind and backscatter (C_N^2) data. The three solid profiles are the radar-measured potential refractive index (N_p), found by constraining the totals to those measured by GPS and using the surface value of N_p to initialize the integration. These radar profiles are in a sense simulations because the sign of the radar-sensed gradient is taken to be that of the balloon sounding, which would not be known in practice. This is a serious problem in some weather/climate conditions, such as southern California, where humidity occasionally increases with height. However, the figures demonstrate the potential accuracy of the method if operated near a weather office where a meteorologist is available to analyze frontal situations, or where regional balloon soundings are available to detect layers of increasing humidity gradient.

IMPACT

The fleet can now monitor radar refractive-index profiles aloft with a ship-based wind profiler if it wants to, but it would have to pay the price in money and maintenance complexity. Because GPS will probably not be able to provide pwv with a moving shipboard receiver, it would presently be necessary to get the equivalent information with a shipboard microwave radiometer.

TRANSITIONS

Microwave radiometers are fairly expensive and require special maintenance. However, it would probably be necessary to have only one profiler system for any normal task force. Planning and cost benefit studies should be done now, and a feasibility study should be initiated aimed at optimum location of a suitable phased array antenna in unused space (the helipad?). Final decisions about profiler deployment in the fleet may depend on the climate and refractive conditions in critically strategic areas of the world. We note that refractive conditions are especially severe in areas such as the Middle East where conditions climatologically similar to southern California exist.

RELATED PROJECTS

This work has been directed and monitored by the Propagation Division of NRaD at San Diego, and is directly related to the surveillance and target identification systems being developed there. It is directly related to all surveillance, EMCON and target identification projects in DOD.

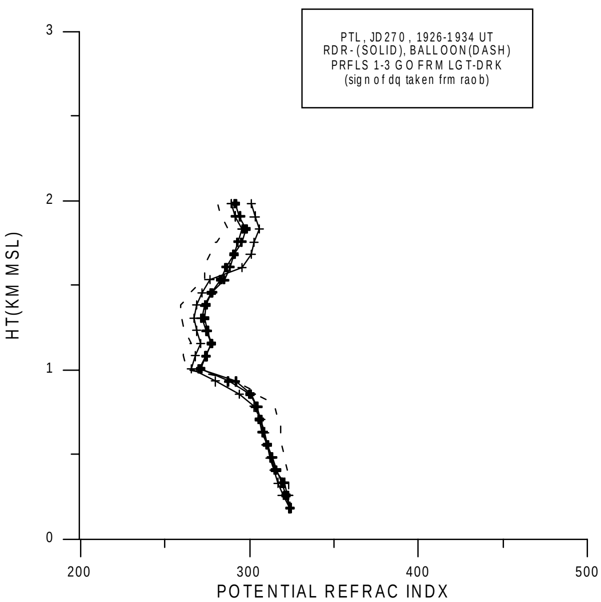
PUBLICATIONS

1) Gossard, E.E., R.B. Chadwick, W.D. Neff and K.P. Moran. 1982. The Use of Ground-Based Doppler Radars to Measure Gradients, Fluxes and Structure Parameters in Elevated Layers. Journal of Applied Meteorology 21: 211-226.

2) Gossard, E.E., J.B. Snider, E.E. Clothiaux, B. Martner, J.S. Gibson, R.A. Kropfli and A.S. Frisch. 1997: The Potential of 8-mm Radars for Remotely Sensing Cloud Drop-Size Distributions. Journal of Atmospheric and Oceanic Technology 13: 201-228.

3) Gossard, E.E., D.E. Wolfe, K.E. Moran, R.A. Paulus, K.D. Anderson and L.T. Rogers. 1998a. Measurement of Clear-Air Gradients and Turbulence Properties with Radar Wind Profilers. Journal of Atmospheric and Oceanic Technology (in press).

4) Gossard, E.E., D.E. Wolfe and B.B. Stankov. 1998b. Measurement of Humidity Profiles in the Atmosphere by Global Positioning System and Radar Wind Profilers. 1998. Journal of Atmospheric and Oceanic Technology (submitted to JTECH).



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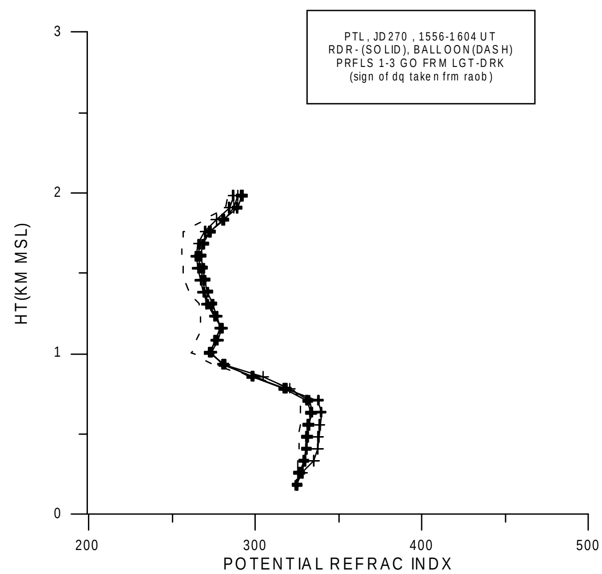

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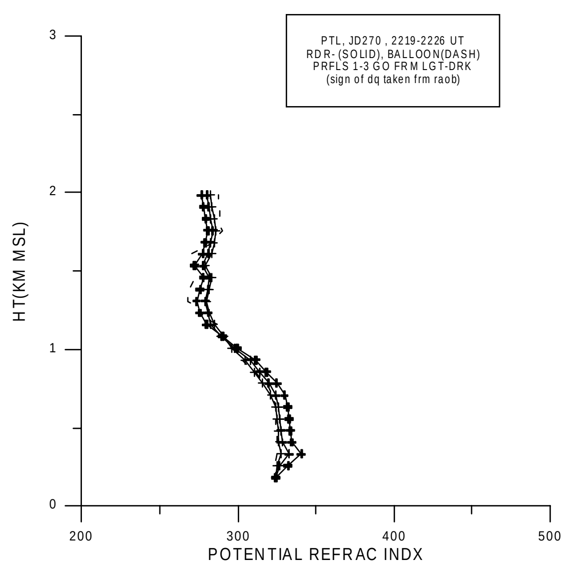

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